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Correction of Simptomatic Flexible Flatfoot - A Review

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Abstract: ***Flatfoot is a common condition in growing-age patients. Despite its common presentation, nowadays surgical indications and treatments are still debated. Arthroereisis is a widely used technique, and several implants designs have been proposed over time. Despite the good results shown in the literature, the main drawback of these techniques has always been the need for a second surgery for implant removal. Bioabsorbable devices have been introduced to overcome this necessity. Correct approach to the patient, indications and contraindications and available studies on bioabsorbable implants for subtalararthroereisis in pediatric flatfoot were analyzed in this narrative review. Even if only a few studies have been published in the literature, bioabsorbable implants showed good clinical results comparable to non-absorbable implants and with a rare necessity for implant removal or revision. When correct indications and proper surgical technique are followed, arthroereisis with bioabsorbable implants appears to be an effective solution for the treatment of pediatric flexible flatfoot.***

Keywords: Bioabsorbable implants, Flatfoot, Arthroereisis, Pesplanus, Calcaneovalgus, Surgical treatment

1. Introduction

Flatfoot is a common condition in growing-age patients [1, 2]. The deformity can be asymptomatic or symptomatic, rigid or flexible and can be either morphological orfunctional.

From a morphological point of view, flatfoot shows a reduction in or absence of the medial arch, a talar adduction and plantar flexion, a valgus hindfoot under weight bearing and different degrees of forefoot supination and abduction [3]. A functional flatfoot is instead characterized by a prevalent or persistent state of pronation during all gait phases.

Several conditions may lead to a flatfoot deformity: congenital synostoses, neuromuscular disorders (cerebral palsy or hypotonia, muscular dystrophies), connective tissue dis- orders (ligament laxity, Ehlers–Danlos syndrome) and post- traumatic, infectious, in inflammatory and iatrogenic sequelae. Despite that, in pediatric patients the deformity is mostly idiopathic; many factors, like obesity [4], morphological alterations in the subtalar joint [5], type of shoes [6], muscular weakness, tendon tears and others [7], may increase the risk of suffering from flatfoot.

Morphological flatfoot in children and teenagers is usually bilateral, with slight or no clinical symptoms; therefore, it is usually well tolerated by the patients. In a functional flatfoot vice versa, the persistent pronation of the subtalar joint, which does not properly alternate between pronation and supination during gait phases, may cause limitations in daily activities such as generalized early fatigue of the foot, ankle or leg, low back, knee or heel pain and medial foot calluses [8] and may also have important consequences in adulthood. Conditions such as hallux valgus/rigidus [9], metatarsalgia, Morton's neuroma, posterior tibialis tendon dysfunction, tarsal tunnel syndrome and subtalar or midtarsal osteoarthritis are reported to be a consequence over time of a non-treated functional flexible flatfoot deformity [10]. Usually, a foot that is morphologically at but works as a normal foot does not require any treatment. On the contrary, a functional and symptomatic flatfoot represents the primary indication for treatment.

Nowadays, surgical indications and treatments are still debated [11–14]. A surgical treatment is usually recommended in patients with functional flatfoot complaining pain and dysfunction after 8 years of age [15]. The results of several surgical approaches are good on a short-to-mid- term, but the literature still lacks long-term results [16, 17].

Surgical treatment offers several possibilities: soft tissue procedures, osteotomies, arthrodesis and arthroereisis. The common goal shared by these techniques is to restore a proper alignment between talus and calcaneus. Arthroereisis is a widely used technique and several implants designs have been proposed over time [15, 18–23]. Despite the good results obtained, the need for a second surgery for the device removal still represents an issue. In order to overcome the necessity of implant removal, different bioabsorbable implants have been proposed over years.

The aim of this narrative review is to provide an overview of the correct approach to the patient, to clarify the most appropriate indications for the procedure and to examine the available literature on the use of bioabsorbable implants for subtalararthroereisis in pediatric flatfoot.

Approach to the patient

The approach to a pediatric flatfoot should be both clinical and radiographical.

As for any other condition, it is crucial to collect thoroughly the history of the patient and perform a complete examination [24]. Real pain is uncommonly reported, and usually, the patient only describes a feeling of early fatigue during daily activities (especially sport-related). If pain is present, it is usually referred to the midfoot at the level of the navicular bone or at the talo-navicular joint. In a rigid flatfoot due to tarsal coalition pain will tend to localize at the sinus tarsi level or below the lateral malleolus.

The examination of the patient must be performed both in a standing position and lying down on the examination table. Diagnostic observations need to focus on the medial arch height, but also on other joints (ankle, knee and hip) [25]. The presence of any ligamentous laxity at the level of the hands, elbows or knees and of any dysmorphism such as an excessive anteversion of the femoral neck, a valgus or recurvation deformity of the knee, or an internal rotation of the tibia should be carefully investigated because they can contribute to foot pronation. The patient has to be evaluated, whilst he is standing up, from behind: The alignment of the heels must be noted as in this condition heels usually show signs of excessive pronation during weight bearing. When looking at the heel from the back of the patient, usually only the fifth toe and half of the fourth toe are seen. Sometimes, in a flatfoot deformity, more of the lateral toe can be seen ("too many toes" sign) [26]. In order to distinguish a morphological flatfoot from a functional one, it is also important to examine the patient investigating for both gait characteristics and functional tests. The patient needs to be observed walking barefooted to identify any eventual gait asymmetry. During walking, signs of functional flatfoot are represented by a collapse of the hindfoot at the moment of contact with the ground, a lack of tibial twisting, an early lifting of the heel and an insufficient boost phase. During tiptoe walking, attention should be paid to the possible reconstruction of the medial longitudinal arch due to the action of the flexor muscles [2]. A flexible flatfoot can be also identified by passively extending the hallux at the metatarsophalangeal joint to end range of motion with the patient in a standing position. In a normal foot, this maneuver causes a shortening and an elevation of the middle arch and an inversion movement of the subtalar joint which clinically reduces the heel valgus and produces an external rotation of the tibio-talar complex (Jack's test) [2, 27]. This correction is caused primarily by the tensioning of the plantar fascia and the short medial muscles. In addition, the forced dorsiflexion of the big toe causes a stretching of the flexor hallucislongus with a hypertonic reaction, resulting in vertical thrust from the bottom upward on the sustentaculumtali which contributes to the inversion of the subtalar joint. Attention should be paid to the flexibility of the Achilles tendon and gastrocnemius because contractures, as the hindfoot deforms into valgus, may aggravate the deformity; the patient should be asked to walk on heels which would be di cult if an Achilles tendon contracture is present. In addition, by observing the patient walking on the outer edge of the foot it is possible to evaluate the restoration of the plantar arch and the functionality of the tibialis anterior muscle; by observing the patient walking on the inside edge of the foot, it is possible to evaluate with more accuracy the subtalar and midtarsal joint motility.

Gait analysis is advised in some cases, when the diagnosis is not clear: Anthropometric measurement, kinematics, dynamics and isokinetics evaluations provide an effective way of measuring the events during gait in order to iden- tify precise di erences between a normal and flatfoot [28]. Flatfoot gait pattern is characterized by several kinematic and electromyographic abnormalities; they consist mainly in a trend for the foot landing with a plantar- flexed ankle as well as an increased dorsiflexion during terminal stance. An eversion joint movement is present throughout the stance phase. Most of the patients have a premature activation of the gastro-soleus complex and the peroneus longus present at heel strike. In summary, the flatfoot shows a reduced load absorbtion ability in early stance and a decreased push-o strength.

With the patient lying down on the examination table, a limited passive dorsiflexion of the tibio-talar joint usually further demonstrates an Achilles tendon contracture [11]. When performing this assessment, the subtalar joint must be inverted to neutral and held locked in that position with a slight hypercorrection of the midtarsal joint in order to isolate and assess the real motion of the talus in the ankle joint [29]. The Silfverskiöld knee flexion test may be used to distinguish between isolated gastrocnemius contracture and combined shortening of the gastrocnemius–soleus complex by measuring the range of ankle dorsiflexion with a 90° exed and straight knee [30].

Subtalar limited mobility or rigidity may suggest a tarsal coalition. A generic neurologic assessment is necessary to diagnose neurologic or myopathic conditions associated with flatfeet.

Footprint analysis using a podoscope is a simple, rapid and cost-effective method. Although many authors [28, 31] advocate its use to analyze the deformity, the results of this technique are not significant for a flatfoot functional analysis [15].

Though a radiologic evaluation is not strictly necessary for the diagnosis of flexible flatfoot, it can be important to assess the severity of the deformity. In the normal foot, the talus posterior facet does not come in contact with the floor of the sinus tarsi; Johnson described what he called sinus tarsi impingement sign present on the lateral radio- graphs caused by the collapse of the talus posterior facet. A weight-bearing lateral radiograph can be used to determine the Meary's angle [1], which evaluates the alignment of the longitudinal axis of the talus compared to the longitudinal axis of the first metatarsal. This angle is ideally 0° [1] in the normal foot, but when measured in a flatfoot deformity it becomes an apex plantar-ward angle. Due to the anatomy of the midfoot, the exact position of the Meary's angle can be both at the talo-navicular joint or at the navicular–cuneiform joint; this can o er a hint as to the etiology of the at foot. Several studies have also demonstrated the association of the Meary's angle position and entity with condition such as tibialis posterior tendon tears [32]. The lateral projection is also useful to determine the angle known as calcaneal pitch which represents the elevation of the calcaneal axis. A line is drawn from the plantar surface of the calcaneus to the inferior border of its distal articular surface. The angle made between this line and the transverse plane represents the calcaneal pitch [33]. A decreased calcaneal pitch is consistent with pesplanus. The normal range varies in the literature, but 18–20° is generally considered the normal range [33]. Another angle which can be identified in the lateral projection is the Moreau–Costa-Bertani angle [34, 35] which corresponds to the angle formed by the line originating from the lower point of the medial sesamoid and the line originating from the lower point of the posterior calcaneal tuberosity, joining in the lower point of the talo-navicular joint (normal values range between 115° and 125°; the foot is considered at if the angle is lower). On both lateral and dorso-plantar views, a normal midtarsal joint should create a continuous smooth cyma line (an architectural term designating the union of two curve lines) between the talo- navicular joint and calcaneocuboid joint. A broken cyma line usually indicates a rotation and plantar flexion of the talus on the calcaneus as typically occurs in flatfoot.

The dorso-plantar projection in weight-bearing condition is used to determine the antero-posterior talo-calcaneal angle (Kite's angle) which is an indicator of a valgus deformity of the hindfoot if greater than 40° [1]. This angle is formed by the intersection of a line bisecting the head and neck of the talus and a line running parallel with the lateral surface of the calcaneus. Measures of the Kite's angles tend to be unreliable because of the overexposure of x-ray images of this particular area of the foot. Another angle useful to deter- mine in the dorso-plantar projection is the talo-navicular coverage angle as described by Sangeorzan et al., which describes the angle between the articular surface of talus and articular surface of navicular bone (normal value less than 7° [36]. The talo-calcaneal "C-sign" can be observed in patients with a subtalar coalition on lateral foot radiographs; this sign represents the bony bridge that extends from the talar dome to the inferior margin of the sustentaculumtali [37]. However, when a tarsal coalition is suspected, TC scan represents the gold standard for the diagnosis and assessment of the condition.

These measurements enable examination only of the static morphology of the foot, and so, an abnormal radio- graphic nding does not represent an absolute indication for surgical treatment.

2. Indications and Contraindications

Indications and contraindications to bioabsorbable implants for subtalararthroereisis are the same as the traditional non-absorbable implants.

Regardless the type of implant, in order to achieve good results with arthroereisis technique it is crucial to assess indications and contraindications. There seems to be a lack in univocal indications for this kind of surgery [11, 13, 38–47], and the question is still controversial in the surgical community.

In several papers, Giannini et al. [9, 11, 15, 37, 48] pro- vided clear indications and contraindications to arthroereisis. According to Giannini, indications to arthroereisis in pediatric patients are represented by [11, 49]:

- Symptomatic functional flexible flatfoot, ideally from 8 to 12 years old, but depending on the skeletal maturity;
- Rigid flatfoot due to bone coalitions (after coalition removal);
- Vertical talus (associated with extensive soft tissue release) Contraindications are represented by:
- Neurologic flatfoot;
- Ligamentous laxity;
- Clubfoot sequelae. In these feet, no muscular rebalance of the foot during growth can be expected. The optimal time window for surgery is still debated. Substantial age variation exists between studies, some including children from 2 to 6 years old [41, 50]. Despite that, the majority of authors agree that the ideal age should range from 8 to 14 years old [21, 43, 51, 52]. The main reason for this indication lies on the physiological foot growth and development. The foot is physiologically at until the age of 4 years and then transforms gradually into a helicoidal structure [1]. From 6 to 8 years old, usually conservative treatment is suggested [11]. Insoles and orthoses have been proposed in younger patients, as well as stretching activities to the Achilles and tibialis posterior tendons. Even if there is poor evidence that validates the efficacy of these treatments [53, 54], during this period a correction is still achievable. This is the reason why most of the surgeons tend to postpone a surgical treatment, in order to be sure that the flatfoot will not improve with time and conservative management. Another reason why surgery is usually not performed under 8 years old is that solid bone tissue should be present [51]. Surgical treatment should be therefore performed when skeletal components are sufficiently developed and the foot still posesses a certain growth potential. In consideration of this, many authors stress the importance of not exceeding the age of 14 years old because foot development would have been almost complete and not enough correction could be obtained [49]. Although some authors have proposed arthroereisis in patients with neurologic flatfoot [41], for many others this condition, as well as flatfoot in ligamentous laxity, represents a contraindication to arthroereisis [15, 51]. During growth, despite the bony correction achieved with the device, the pathological muscular or ligamentous condition does not allow muscular rebalance and foot remodeling activity over time [15, 51]. This concept is supported by the results obtained on these patients by some authors, often unsatisfactory [12, 41]. For all the above reasons, some authors recommend to perform a Grice subtalar arthrodesis on these patients [15].

In case of clubfoot sequelae, when a iatrogenic flatfoot is created by overcorrection of an equinus–varus-supinated deformity, calcaneal osteotomies or subtalar arthrodesis can be performed according to a flexible or rigid deformity, respectively [15].

3. Related Procedures

Flexible flatfeet are not always simple deformities that can be corrected by arthroereisis only. In some cases, depending on the presenting condition, it is necessary to perform associated procedure to obtain a satisfactory correction. Particular attention must be paid to possible Achilles tendon contractures and to the presence of a prominent or accessory navicular bone. During surgery, after the positioning of the device, ankle dorsiflexion with the knee in extended position must be evaluated. If the dorsiflexion is limited (less than 90°), a lengthening of the Achilles tendon (usually percutaneously) must be performed. If a prominent or accessory navicular bone is present or a Meary's angle of more than 10° at the talonavicular joint is observed on lateral X-rays, a medial procedure, with prominence resection or accessory navicular removal associated with a tibialis posterior tendon retention, needs to be performed as well [49]. Sometimes, this procedure can be combined with a tibialis anterior tenodesis [55]. After arthroereisis procedure is performed, some supination of the forefoot may occur. If the forefoot compensates with time by increasing the first ray plantar flexion, a plantigrade foot is maintained. On the contrary, if the supination exceeds this adaptive capability, during the foot at phase of gait the hindfoot has to evert to maintain the forefoot in a plantigrade position. For this reason, when a residual fixed forefoot supination is present after the hindfoot correction, some authors suggest associating an opening wedge osteotomy of the medial cuneiform [56].

Bioabsorbable implants for subtalararthroereisis in the literature

Although the use of bioabsorbable implants for subtalararthroereisis is not a new concept, only few papers related to this topic are reported in the literature (Tables 1, 2). The first reported paper on bioabsorbable implants for subtalararthroereisis was published in 2001 by Giannini et al. [11]. Twenty-one children with bilateral flexible flatfoot were included in the study and treated with bioabsorbableendoorthotic implant. At an average 4-year follow-up, a significant decrease in discomfort was observed, from 81% preoperatively to 5% postoperatively. Mean clinical and radiographic parameters all significantly improved at follow-up. Magnetic resonance imaging was performed periodically to evaluate the implant behavior over time. At 4-year follow-up, and pediatric patients (66 adult and 29 pediatric) affected by flatfoot treated with subtalar joint endo-orthotic arthroereisis. In the series, 26 pediatric patients were treated with bioabsorbable implants. At a minimum 12-month follow- up, the implant survival rate was 85%. In the remaining 15% implants were removed due to pain at the sinus tarsi level. Positive results were also obtained by Jay et al. [58] on 20 children with 34 flexible flatfeet evaluated at a 18.4- month average follow-up. Clinical parameters significantly improved in all cases. No major complications were recorded in the series. Thirteen minor complications occurred, such as occasional pain in the initial postoperative period or transient sinus tarsi pain. Ruozi et al. [59] reported the results of 59 flexible flatfeet in 33 patients treated with endo-orthotic bioabsorbable implant at a 4.3-year mean follow-up. Good clinical and radiographic results were recorded almost in the totality of patients at the last follow-up. Despite that, eight patients (25.4% of feet) required removal of the implant due to pain and inflammation. In the study, magnetic resonance imaging evaluation together with laboratory in vivo observations and chemical–physical characterization of the removed fragments revealed a longer bioabsorption period required (from 7 to 9 years) if compared to the results previously reported by Giannini et al. [11]. Since during growth flexible

Table 1: Available bioabsorbable implants for subtalararthroereisis

Implant	Manufacturer	Available sizes (mm)
BFFI®	NovagenitSrl	8–10
BioBlock®	Integra LifeSciences Corporation	8–9–10–11–12
ProStop Plus®	Arthrex Inc.	8–9–10–11–12
RSB CS®	Limacorporate Spa	7–9

The bioabsorbable device was almost completely disappeared in all cases. Only two complications were observed in the series: Small fragments of the implant impinged against the shoes at 1- and 2-year follow-up. The problem spontaneously resolved in both patients with reabsorption of the material over time and did not require any additional surgery. Giannini et al. [37] reported the results of 12 children with painful bilateral flatfoot due to a talo-calcaneal coalition. All patients were treated by resection of the coalition and subtalararthroereisis with endo-orthotic bioabsorbable implant. Clinical parameters significantly improved at 40-month final follow-up. No poor results, or subjective or objective complications, were reported in the series. Baker et al. [57] published in 2013 a retrospective review on 95 adult

Table 2: Bioabsorbable implants for subtalararthroereisis in the literature

Authors	Implant type	Number of patients	Age range (years)	Follow-up (years)	Clinical results	Complications	Removal rates
Giannini et al. [11]	BFFI®/Endorthe- sis/Stryker Howmedica	21 (42 proce- dures)	8-15	4	Good to excellent 95%, Fair 5%, Poor 0%	2 (4.7%	None
Giannini et al. [37]	BFFI®/Endorthe- sis/Stryker Howmedica	12 (14 proce- dures)	9-18	2-5	Good to excellent 78.5%, Fair 21.5%, Poor 0%	None	None
Baker et al. [57]	ProStop®/ Endorthesis/ Arthrex	13 (26 proce- dures)	9-17	Not reported	No clinical data reported	No data	3 (11.5%)
Jay et al. [58]	Not specified	20 (34 proce- dures)	4-17	0,5-3	Good to excellent 95%, Fair 5%, Poor 0%	11 (32%)	None
Ruozi et al. [59]	BFFI®/Endorthe- sis/Novagenit	33 (59 proce- dures)	8-16	3-8	Good to excellent 85%, Fair 13%, Poor 2%	15 (25%)	25.4%
Faldini et al. [9]	BFFI®/Endorthe- sis/Novagenit	32 (64 proce- dures)	8-12	2-6	Good to excellent 100%	4 (6%)	1%
Giannini et al. [60]	RSB CS/Calca- neo-stop screw/ Lima	44 (88 proce- dures)	8-14	4-5	Good to excellent 96%, Fair 0%, Poor 4%	2 (2%)	2% screw head

flatfoot could present associated with hallux valgus, Faldini et al. [9] published the results of 32 children affected by bilateral hallux valgus and flexible flatfoot who underwent surgical treatment combining a rst metatarsal osteotomy and subtalararthroereisis with endo-orthotic bioabsorbable implant. At an average follow-up of 5 years, clinical and radiographic parameters all significantly improved. In the series, one complication related to the bioabsorbable implant occurred: A displacement of the device, with pain, swell- ing and inflammatory skin reaction over the sinus tarsi was observed and a second surgery to replace the implant was performed. After the positive results obtained with the endo-orthotic implant, Giannini et al. reported in 2017 the results of a bioabsorbablecalcaneo-stop device implanted on 44 children with bilateral flexible flatfoot [60]. Mean clinical and radiographic parameters all significantly improved at follow-up. Magnetic resonance imaging performed on 11 patients at a minimum 5-year follow-up revealed that the implant was almost completely biodegraded. Two complications occurred in the series: Revision surgery was performed in two patients 4 and 5 months after implantation, respectively, for implant breakage at head-screw junction.

4. Discussion

Arthroereisis is widely adopted in Europe for the treatment of flexible flatfoot in pediatric population [11, 61–64]. Regardless of implant design or material, the technique aims to limit, by placing a device in the sinus tarsi, the excessive subtalar eversion and to maintain the physiological alignment between talus and calcaneus during bone remodeling. The effectiveness of the arthroereisis procedure with non- absorbable implants in pediatric patients has been widely confirmed by the most recent studies at medium-term follow-up [9, 11, 13, 51]. Despite the results of the different techniques being all similar, the only setback with the majority of these procedures is represented by the need for a second surgery for implant removal. Although many authors perform implant removal only in case of pain and inflammatory reaction [12, 14, 41, 65], in Europe there is agreement on the need of performing screw removal in all cases from 2 to 3 years after implantation, depending on patient skeletal maturity [38, 43, 52, 66]. In the attempt to avoid a second surgery for implant removal, the properties of bioabsorbable materials have been applied in recent years to arthroereisis devices [37, 57, 60, 67, 68].

In this narrative review, correct approach to the patient and proper indications and contraindications for subtalararthroereisis in pediatric flatfoot through an analysis of the available literature were investigated. Moreover, current studies on bioabsorbable implants for subtalararthroereisis in pediatric flatfoot were included, regardless of methodology or level of evidence.

The overall clinical results of bioabsorbable implants are comparable to that observed with non-absorbable implants with a rare necessity for implant removal or revision [9, 11, 57, 59].

In respect of clinical results, disagreement on the behavior and survival of bioabsorbable implant over time still exists. There is not an univocal consensus on the time needed for the implant to be completely reabsorbed [59]. Giannini et al. [11] suggest a complete implant reabsorption over 4–5 years postoperatively [11, 60]; other studies prove how this period could be slightly longer [59]. The poly-L- lactide degradation process may vary depending on several factors: polymer chemical structure, processing conditions and storage history, implant molecular weight, crystallinity and size [59, 67]. The device resorption process may require more time even in relation to the implantation site. The sinus tarsi area, being extra-osseous, is poorly vascularized and has a low cellularity. For this reason, the bioabsorption of the implant may be hampered and it may require more time [59], especially if invasive surgical approaches, which may compromise the vascularization, are used. There are concerns about the possible e ects related to the implant bio-absorption process. Poly-L-lactide hydrolytically degrades by the random scission of the ester backbone into lactic acid subsequently broken down into water and carbon dioxide via the citric acid cycle (Krebs cycle) [69]. This process within the body inevitably results in some form of cellular response and may cause mild and temporary inflammatory reactions. Giannini et al. in their first publication reported two cases of inflammation (4.7%) and impingement between small implant fragments and the shoes spontaneously resolved in both cases with the progressive resorption of the material. The percentages of a second surgery for bioabsorbable implant removal vary in the literature: Baker removed the implant in 15% of the treated pediatric patients, Ruozi et al. in 25.4%, Faldini et al. in 1.5% and Giannini et al. in 2.3% with the use of a reabsorbable calcaneo-stop device. If temporary inflammatory reactions seem to be reasonably related to the implant bioabsorption process, and usually resolving spontaneously with time without requiring any further treatment [11, 49], early implant ruptures or mobilization may be caused by excessive stresses on the implant.

In order to avoid excessive implant stresses and early complications, such as implant ruptures, it is essential to adopt a correct surgical technique and to follow the correct indications for treatment. Neglecting those will almost surely lead to complications.

Attention to surgical technique represents the first step for a successful placement of the device. During surgery, subtalar soft tissue structures must be preserved, thus preventing bone and joint irritation and leaving tissue to secure local fixation of the implant within the sinus tarsi [13]. The proper implant size is also important: It should limit excessive subtalar joint eversion and allow for a few degrees of remaining eversion only. If the device inserted is too large, the subtalar joint motion will be overly limited, thus resulting in pain. In the opposite case, if the device is too small, the correction will not be satisfactory enough and linked to a higher risk of implant mobilization [56]. Giannini et al. reported in several papers [9, 11] the use of an 8-mm screw in the majority of cases, thus further confirming the results in the literature which showed the sinus tarsi to be of approximately 8 mm in height [68, 70, 71]. Obesity may play a role in causing excessive stresses on the implant and for some authors rep- resents a contraindication [60]. Likewise, advanced patient ages might affect the results for the same reason. Since the equinus deformity is one of the major drivers of foot pro- nation, it is crucial to preoperatively and intraoperativelyasses when Achilles tendon lengthening is required. An undetected residual equinus would add extra stress to the implant, thus leading to a higher risk of implant breakage [60]. Another possible cause for implant failure is an insuficient forefoot correction. After arthroereisis procedure is performed, some supination of the forefoot may occur. If the forefoot has to evert in order to maintain a plantigrade position, this can lead to increased compressive stresses to the implant. For this reason, Vulcano et al. [56] suggested to associate an opening wedge osteotomy of the medial cuneiform if a residual fixed forefoot supination is present after the hindfoot correction.

The final component necessary for a successful procedure is postoperative care. It is advisable for the patient to avoid jumping or running for a few months after surgery, firstly to allow healing of the surgical site and adjustment of the implant in its correct position and then secondly because a temporary internal rotation and supination of the foot may occur, causing instability during normal daily activity and leading to ankle sprains which may cause early implant dis- placement [9].

In the rare cases, when the implant must be removed due to complications, it may be replaced during the same operation with an implant of different size, type or position, usually with good results and complete pain resolution [9, 60]. However, some studies reported that, even if the device is prematurely broken or removed, the position of the pediatric foot maintains a certain degree of correction [51, 60, 72–75].

5. Conclusions

Arthroereisis of the subtalar joint is the most used surgical technique in Europe for the management of pediatric at- foot. Nowadays, only few papers regarding bioabsorbable implants for subtalararthroereisis have been published in the literature. The results reported by authors vary in terms of implant survival rate, but are di cult to compare because they present different indications for surgery, associated procedures performed and follow-up periods. Temporary inflammatory reactions related to the material may occur, but they usually resolve over time and surgery should not be considered as the initial treatment at their first appearance. However, when correct indications and proper surgical technique are followed, regardless of the implant type or design, arthroereisis with bioabsorbable implants appears to be an effective solution for pediatric flexible flatfoot, with favorable mid-term clinical outcome, comparable to non-absorbable implants, and rare complications related to the material, thus allowing contemplating further surgery only in exceptional cases.

References

[1] Coughlin MJ, Mann RA (2001) Chirurgia del Piede e dellaCav- iglia. 7th edn. vol 1, VerduciEditore, Rome

[2] Solomon L, Warwick D, Nayagam S (2010) Apley's system of orthopaedics and fractures, 9th edn. Hodder Arnold, London, pp 596–600

[3] Kim M-K, Lee Y-S (2013) Kinematic analysis of the lower extremities of subjects with at feet at di erent gait speeds. J PhysTherSci 25(5):531–533

[4] Pourghasem M, Kamali N, Farsi M, Soltanpour N (2016) Preva- lence of atfoot among school students and its relationship with BMI. ActaOrthopTraumatolTurc 50(5):554–557

[5] Kothari A, Bhuva S, Stebbins J, Zavatsky AB, Theologis T (2016) An investigation into the aetiology of exible at feet. Bone Jt J 98–B(4):564–568

[6] Gould N, Moreland M, Trevino S, Alvarez R, Fenwick J, Bach N (1990) Foot growth in children age 1 to 5 years. Foot Ankle. 10(4):211–213

[7] Smith MA (1990) Flat feet in children. BMJ Br Med J. 301(6758):942

[8] Herring JA (2013) Tachdjian's Pediatric Orthopaedics. 5th edn. Elsevier, Philadelphia

[9] Faldini C, Nanni M, Traina F, Fabbri D, Borghi R, Giannini S (2016) Surgical treatment of hallux valgus associated with exibleatfoot during growing age. IntOrthop 40(4):737–743

[10] Benedetti MG, Ceccarelli F, Berti F, Luciani D, Catani F, Faldini C et al (2011) Diagnosis of exibleatfoot in children: a system- atic clinical approach. Orthopedics 34(2):94

[11] Giannini S, Ceccarelli F, Benedetti MG, Catani F, Faldini C (2001) Surgical treatment of exibleatfoot in children. J Bone JtSurg Am 83(2 suppl 2):S73–S79

[12] Mosca VS (2010) Flexible atfoot in children and adolescents. J Child Orthop 4(2):107

[13] Needleman RL (2005) Current topic review: subtalararthro- ereisis for the correction of exibleatfoot. Foot Ankle Int 26(4):336–346

[14] Verheyden F, Vanlommel E, Van Der Bauwhede J, Fabry G, Molenaers G (1997) The sinus tarsi spacer in the operative treatment of exible at feet. ActaOrthopBelg 63(4):305–309

[15] Giannini S, Kenneth A, Johnson Memorial Lecture (1998) Operative treatment of the atfoot: why and how. Foot Ankle Int 19(1):52–58.

[16] Marengo L, Canavese F, Mansour M, Dimeglio A, Bonnel F (2017) Clinical and radiological outcome of calcaneal length- ening osteotomy for flatfoot deformity in skeletally imma- ture patients. Eur J OrthopSurgTraumatol 1–8. doi:10.1007/ s00590-017-1909-9

[17] Yontar NS, Ogut T, Guven MF, Botanlioglu H, Kaynak G, Can A (2016) Surgical treatment results for exibleatfoot in ado- lescents. ActaOrthopTraumatolTurc 50(6):655–659

[18] Cashmere T, Smith R, Hunt A (1999) Medial longitudinal arch of the foot: stationary versus walking measures. ActaOrthopTraumatolTurc 20(2):112–118

[19] Lin Y-C, Kwon JY, Ghorbanhoseini M, Wu JS (2016) The Hind- foot Arch. RadiolClin North Am 54(5):951–968

[20] Peterson H (1986) Growing pains. PediatrClin North Am 33(6):1365–1372

[21] Jerosch J, Schunck J, Abdel-Aziz H (2009) The stop screw technique—a simple and reliable method in treating exibleatfoot in children. Foot Ankle Surg 15(4):174–178

[22] Schon LC (2007) Subtalararthroereisis: a new exploration of an old concept. Foot Ankle Clin 12(2):329–339

[23] Kido M, Ikoma K, Hara Y, Imai K, Maki M, Ikeda T et al (2014) E ect of therapeutic insoles on the medial longitudinal arch in patients with atfoot deformity: a three-dimensional loading computed tomography study. ClinBiomech (Bristol, Avon). NIH Public Access 29(10):1095–1098
[24] Dare DM, Dodwell ER (2014) Pediatric atfoot: cause, epi- demiology, assessment, and treatment. CurrOpinPediatr 26(1):93–100
[25] Giannini S, Ceccarelli F (1998) The flexible flat foot. Foot Ankle Clin 3:573–592
[26] Kwon JY, Myerson MS (2010) Management of the exible at foot in the child: a focus on the use of osteotomies for correc- tion. Foot Ankle Clin 15(2):309–322
[27] Rose GK, Welton EA, Marshall T (1985) The diagnosis of at foot in the child. J Bone Joint Surg Br 67(1):71–78
[28] Giannini S, Catani F, Ceccarelli F, Girolami M, Benedetti MG (1992) Kinematic and isokinetic evaluation of patients with at foot. Ital J OrthopTraumatol 18(2):241–251
[29] Bouchard M, Mosca VS (2014) Flatfoot deformity in children and adolescents: surgical indications and management. J Am AcadOrthopSurg 22(10):623–632
[30] Singh D (2013) Nils Silfverskiöld (1888–1957) and gastrocne- mius contracture. Foot Ankle Surg 19(2):135–138
[31] Leardini A, Benedetti MG, Berti L, Bettinelli D, Nativo R, Giannini S (2007) Rear-foot, mid-foot and fore-foot motion during the stance phase of gait. Gait Posture 25(3):453–462
[32] Lin Y-C, Mhuircheartaigh JN, Lamb J, Kung JW, Yablon CM, Wu JS (2015) Imaging of adult atfoot: correlation of radiographic measurements with MRI. Am J Roentgenol 204(2):354–359
[33] Kaschak TJ, Laine W (1988) Surgical radiology. ClinPodiatr Med Surg 5(4):797–829
[34] Moreau M, Costa-Bertani G (1943) Roentgen study of at foot. Year B Radiol 81:82
[35] Benedetti MG, Berti L, Straudi S, Ceccarelli F, Giannini S (2010) Clinicoradiographic assessment of exibleatfoot in children. J Am Podiatr Med Assoc 100(6):463–471
[36] Sangeorzan BJ, Mosca V, Hansen ST (1993) E ect of calcaneal lengthening on relationships among the hindfoot, midfoot, and forefoot. Foot Ankle 14(3):136–141
[37] Giannini S, Ceccarelli F, Vannini F, Baldi E (2003) Operative treatment of atfoot with talocalcaneal coalition. ClinOrthopRelat Res 411:178–187
[38] De Pellegrin M, Moharamzadeh D, Strobl WM, Biedermann R, Tschauner C, Wirth T (2014) Subtalar extra-articular screw arthroereisis (SESA) for the treatment of exibleatfoot in chil- dren. J Child Orthop 8(6):479–487
[39] deRetana P, Álvarez F, Viladot R (2010) Subtalararthroereisis in pediatric atfoot reconstruction. Foot Ankle Clin 15(2):323–335
[40] Dennyson WG, Fulford GE (1976) Subtalar arthrodesis by cancellous grafts and metallic internal fixation. Bone Jt J 58–B(4):507–510
[41] Kelikian A, Mosca V, Schoenhaus HD, Winson I, Weil L (2011) When to operate on pediatric atfoot. Foot Ankle Spec 4(2):112–119
[42] Harris EJ, Vanore JV, Thomas JL, Kravitz SR, Mendelson SA, Mendicino RW et al (2004) Diagnosis and treatment of pediatric flatfoot. J Foot Ankle Surg 43(6):341–373
[43] Kellermann P, Roth S, Gion K, Boda K, Tóth K (2011) Calca- neo-stop procedure for paediatricflexible flatfoot. Arch Orthop Trauma Surg 131(10):1363–1367
[44] Roth S, Roth A, Jotanovic Z, Madarevic T (2013) Navicularindex for differentiation of flatfoot from normal foot. IntOrthop 37(6):1107
[45] Shah NS, Needleman RL, Bokhari O, Buzas D (2015) 2013 subtalararthroereisis survey: the current practice patterns of members of the AOFAS. Foot Ankle Spec 8(3):180–185
[46] Usuelli FG, Montrasio UA (2012) The calcaneo-stop procedure. Foot Ankle Clin 17(2):183–194
[47] Vulcano E, Maccario C, Myerson MS (2016) How to approach the pediatric flatfoot. World J Orthop 7(1):1
[48] Giannini S, Ceccarelli F, Girolami M, Vincenti G (1985) Il trat- tamento del piedepiatto infantile con endortesi ad espansione, tecnica e valutazionedeiprimi 50 casiconsecutivi. Chir del piede
[49] Giannini S, Faldini C, Luciani D, Cadossi M, Capra P, Persiani V et al. (2010) Piedepiatto: endortesiriassorbibile. G Ital di Ortop e Traumatol. 36:278–284
[50] Metcalfe SA, Bowling FL, Reeves ND (2011) Subtalar joint arthroereisis in the management of pediatric flexible flatfoot: a critical review of the literature. Foot Ankle Int 32(12):1127–1139
[51] Roth S, Sestan B, Tudor A, Ostojic Z, Sasso A, Durbesic A (2007) Minimally invasive calcaneo-stop method for idiopathic, exiblepesplanovalgus in children. Foot Ankle Int 28(9):991–995
[52] Pavone V, Costarella L, Testa G, Conte G, Riccioli M, Sessa G (2013) Calcaneo-stop procedure in the treatment of the juvenile symptomatic atfoot. J Foot Ankle Surg 52(4):444–447
[53] Zhai JN, Qiu YS, Wang J (2016) E ects of orthotic insoles on adults with exibleatfoot under different walking conditions. J PhysTherSci 28(11):3078
[54] Sim-Fook L, Hodgson AR (1958) A comparison of foot forms among the non-shoe and shoe-wearing Chinese population. J Bone JtSurg Am 40–A(5):1058–1062
[55] Miller O (1927) A plastic flat foot operation. Am J Surg 2(3):286–287
[56] Vulcano E, Maccario C, Myerson MS (2016) How to approach the pediatric atfoot. World J Orthop. 7(1):1–7
[57] Baker JR, Klein EE, Weil L, Weil LS, Knight JM (2013) Retro- spective analysis of the survivability of absorbable versus non- absorbable subtalar joint arthroereisis implants. Foot Ankle Spec 6(1):36–44
[58] Jay RM, Din N (2013) Correcting pediatric atfoot with subta- lararthroereisis and gastrocnemius recession. Foot Ankle Spec 6:101–107. doi:10.1177/1938640012470714
[59] Ruozi B, Belletti D, Manfredini G, Tonelli M, Sena P, Vandelli MA et al (2013) Biodegradable device

applied in atfoot surgery: comparative studies between clinical and technological aspects of removed screws. Mater SciEng 33(3):1773–1782. doi:10.1016/j. msec.2012.12.093
[60] Giannini S, Cadossi M, Mazzotti A, Persiani V, Tedesco G, Romagnoli M et al (2017) Bioabsorbablecalcaneo-stop implant for the treatment of exibleatfoot: a retrospective cohort study at a minimum follow-up of 4 Years. J Foot Ankle Surg 56(4):776– 782. doi:10.1053/j.jfas.2017.02.018
[61] Burutaran JM (1979) El calcaneo-stop para el tratamiento del valgo de talon infantil. Chir del piede 3:319–322
[62] Milano L, Scala A (1985) La risiextrarticolaredellasottoastra- galica con endortesicalcanealeneltrattamentochirurgicodelledeformità in valgo del calcagno. ChirPiede. 9:303–322
[63] Castaman E (1985) L'intervento di calcaneo-stop nelpiedepiattovalgo. ChirPiede. 9:319–329
[64] Magnan B, Baldrighi C, Papadia D (1997) Flatfeet: comparison of surgical techniques. Result of study group into retrograde endorthesis with calcaneus-stop. Ital J PedOrthop. 13:28–33
[65] Bauer K, Mosca VS, Zionts LE (2016) What's new in pedi- atric flatfoot? J PediatrOrthop 36(8):865–869. doi:10.1097/ BPO.0000000000000582
[66] Giannini S, Girolami M, Ceccarelli F (1985) The surgical treatment of infantile at foot. A new expanding endo-orthotic implant. Ital J OrthopTraumatol 11(3):315–322
[67] Sena P, Manfredini G, Barbieri C, Mariani F, Tosi G, Ruozi B et al (2012) Application of poly-L-lactide screws in at foot surgery: histological and radiological aspects of bio-absorp- tion of degradable devices. HistolHistopathol 27(4):485–496. doi:10.14670/HH-27.485
[68] Saxena A, Nguyen A (2007) Preliminary radiographic find- ings and sizing implications on patients undergoing bioabsorb- able subtalararthroereisis. J Foot Ankle Surg 46(3):175–180. doi:10.1053/j.jfas.2007.01.009
[69] vonRecum HA, Cleek RL, Eskin SG, Mikos AG (1995) Degradation of polydispersed poly(l-lactic acid) to modulate lactic acid release. Biomaterials 16(6):441–447. doi:10.1016/0142-9612(95)98816-W
[70] Bali N, Theivendran K, Prem H (2013) Computed tomogra- phy review of tarsal canal anatomy with reference to the tting of sinus tarsi implants in the tarsal canal. J Foot Ankle Surg 52(6):714–716. doi:10.1053/j.jfas.2013.07.008
[71] Kleipool RP, Blankevoort L, Ruijter JM, Kerkhoffs GMMJ, Oostra RJ (2017) The dimensions of the tarsal sinus and canal in different foot positions and its clinical implications. Clin Anat. doi:10.1002/ca.22908
[72] Nelson SC, Haycock DM, Little ER (2004) Flexible flatfoot treatment with arthroereisis: radiographic improvement and child health survey analysis. J Foot Ankle Surg 43(3):144–155. doi:10.1053/j.jfas.2004.03.012
[73] Zaret DI, Myerson MS (2003) Arthroerisis of the subtalar joint. Foot Ankle Clin 8(3):605–617
[74] Kuwada GT, Dockery GL (1988) Complications following traumatic incidents with STA-peg procedures. J Foot Surg. 27(3):236–239
[75] Rockett AK, Mangum G, Mendicino SS (1998) Bilateral intraosseous cystic formation in the talus: a complication of subtalararthroeresis. J Foot Ankle Surg 37(5):421–425